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1. Purpose. The change provides standards and recommendations to build infra-red aircraft deicing facilities and adds anaerobic bioremediation as an alternative method to mitigate the runoff effects of de/anti-icing products.

2. Principal Changes.

a. A new Appendix 1, *Design of Infra-red Deicing Facilities*, was added that provides standards and recommendations to build aircraft deicing facilities employing infra-red energy unit systems that are gas-

powered and computer-controlled. The appendix explicitly states that such facilities are only capable of performing deicing operations. When an aircraft requires anti-icing, the appendix explicitly states that an appropriate anti-icing *fluid* is required.

b. Chapter 5, *Water Quality Mitigation*, adds the technological approach of anaerobic bioremediation as another proven method available to airport authorities for mitigating the effects by de/anti-icer products found in storm water runoff.

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CHAPTER 5. WATER QUALITY MITIGATION

24. RUNOFF MITIGATING STRUCTURES. Since deicing/anti-icing fluids are chemical products with environmental consequences, deicing facilities shall have runoff mitigating structures. The recommended structures are those that comprise a mitigating alternative that collects and retains runoff for proper disposal or recycling. In terms of structural best management practices (BMPs), this approach to "control the source" offers airport managers an effective and economical means to comply with storm water permitting requirements. Change 1 to AC 150/5320-15, *Management of Airport Industrial Waste*, provides additional BMPs to mitigate various types of pollutants from entering storm water runoff conveyances.

a. Treatment Advantages. The approach to "control the source" offers two treatment advantages. First, it lessens the difficulty of dealing with the facility's deicer runoff by isolating it from airfield storm sewers or from terminal areas that do not divert seasonal flows of glycols. Second, deicing facilities enhance the feasibility of recycling glycols by collecting higher glycol concentrations, as compared to drainage systems where glycols are further diluted with other runoff and precipitation.

b. Treatment Parameters. Of the discharge parameters the alternative needs to mitigate, biochemical oxygen demand (BOD) and toxicity are the primary runoff effects requiring control. The additives in fluids may have an effect on the overall biodegradability. Depending on the type of discharge permit, the alternative would need to monitor specific items, generally based on BOD₅, chemical oxygen demand (COD), total organic carbon (TOC), total suspended solids (TSS), oil/grease, pH, and flow rate limits.

25. MITIGATION ALTERNATIVES. The mitigation alternative should allow users of the deicing facility continued use of deicing fluids within the framework of Federal, state, and local storm water runoff regulations (discharge permits). It is strongly recommended that the proposed alternative be reviewed by the Federal, state, or local environmental authority having jurisdiction to verify its effectiveness to place the deicing facility in regulatory compliance. Prior to final selection, all alternatives should be evaluated on a life cycle cost basis to avoid an accepted long term alternative with a short useful life, for an example see paragraph 26, PUBLICLY OWNED TREATMENT WORKS (POTW). Additionally, it should reflect the best alternative afforded by the facility's site and integration with the airport master drainage plan. A few alternatives are:

a. off-airport biochemical treatment of facility runoff at POTWs by way of a sanitary sewer. See paragraph 26, Publicly Owned Treatment Works, for additional guidance.

b. on-airport detention basin with pump station for discharging metered runoff to receiving waters by an airport storm sewer. See paragraph 27, Detention Basins, for additional guidance.

c. on-airport anaerobic biochemical reactor for pre-treatment of runoff prior to discharge to POTWs or detention basin. See paragraph 30, Anaerobic Bioremediation Systems.

d. on-airport underground storage tanks (UST) or concrete vaults for detention of runoff for hauling tankers to siphon for proper disposal. For airports lacking the physical space for detention ponds, USTs near the facility is an alternative. See paragraph 28, Underground Storage Tanks, for additional guidance.

e. on-airport recycling system. See paragraph 29, Recycling Glycol Fluids, for additional guidance.

f. diversion boxes for diverting seasonal glycol runoff to a specific location, such as a detention basin.

Depending on the site and storm water permitting requirements, one of the above alternatives and/or other technologies working in tandem should provide the airport manager with an effective alternative acceptable to Federal, state, and local environmental authorities.

26. PUBLICLY OWNED TREATMENT WORKS (POTW). Off-airport biochemical treatment of facility runoff at POTWs is a proven mitigation alternative. This alternative normally requires the airport manager to monitor flow volumes and pretreat glycol contaminated storm water to protect the receiving POTW facility, for example see paragraph 30. Areas of probable pretreatment are high BOD₅, COD, TOC, TSS, pH, and oil/grease. Of these, treatment of glycol BOD loads is of primary concern since some data measure an impact load of approximately 3,000 times that of raw human sewage. To protect POTW, the United States Environmental Protection Agency (USEPA) developed a national pretreatment strategy (1977) under the Clean Water Act. The regulations were published as 40 CFR Part 403. Regardless of the size of the surrounding community, airport authorities considering this alternative should not only evaluate the POTW's current capacity but whether it can accept both future load demands from the airport and a growing community.

27. DETENTION BASINS. For airports with available physical space, an economical alternative to treating "first flush" runoff from deicing facilities is by a single or series of detention basins. The state or local authority having jurisdiction generally sets construction and design standards. Impermeable liners to protect the groundwater and/or monitoring wells to detect breached liners are likely to be required.

a. Sizing. Biodegradability rate, which varies by glycol types, is a primary factor for determining basin capacity. Basin capacity can be reduced by taking into account the slower microbial activity during the winter season and the greater quantity of available oxygen in colder water. Detention of ethylene glycol, which degrades quicker than propylene glycol, permits earlier metered discharges and, thus, reduced basin capacity.

b. Mechanical Aeration. The quick consumption of available oxygen levels within basins by glycol can lead to anaerobic conditions (lack of oxygen). This condition leads to potential septic conditions (undesirable odors) due to the adverse impacts to bacterial generation necessary for glycol degradation. A recommended corrective action is to install a mechanically aerated system to replenish oxygen levels. This supplemental acceleration of biodegradation and thus, earlier discharging of glycols, further reduces a basin's capacity. The installed system should maintain dissolved oxygen levels at the level that places the alternative in environmental compliance. For some basins, pump stations and force mains may be required if the discharge cannot reach the desired outfall locations.

c. Wildlife Management. AC 150/5320-15 and AC 150/5200-33, *Hazardous Wildlife Attractants on or near Airports*, provide recommended configurations and site location for detention basins from a wildlife standpoint. Non-enclosed detention basins shall not be situated under or adjacent to runway approaches.

d. Other Features. Additional design features may be necessary if runway deicers containing urea or other effluents are collected within a basin that contains nutrients for plant growth. For instance, the growth of algae blooms under the right conditions may be for some environmental authorities regarded as suspended solids. Their inclusion to the TSS discharge limit may cause this alternative to exceed permitted levels.

28. UNDERGROUND STORAGE TANKS (UST). UST systems that collect ethylene glycol deicing fluids are regulated under the USEPA UST regulations, i.e., 40 CFR, Parts 280 and 281. Though other types of glycols are available which may not be regulated, this alternative has the potential to collect a regulated substance such as aviation fuel. Because of this potential and future use of ethylene glycol based fluids by tenants, it is recommended that this alternative be designed in accordance with applicable USEPA and state UST

regulations. For facilities used on a yearly basis, this alternative may collect regulated substances when the deicing pads are used for washing the exterior of aircraft. If a UST is the final collection point, a rigid pad with catch basin may be required for hauling tankers.

29. RECYCLING GLYCOL FLUIDS. Depending on the content nature of the runoff and economics, improved technologies are available for recycling spent glycol fluids collected at concentrations of 5 percent and, under certain conditions, even lower percentages. In terms of recycling fluid types that offer longer holdover times as compared to type I fluids, the fluid types are normally more demanding to recycle because of special polymers. This however, is resolved simply by the addition of an extra processing step, thus making recycling an economical consideration. Recycling provides airport management with two valued resources. The first resource is recycled glycol and the second resource is water. Besides recouping some of the chemical cost for glycol and the utility cost for water, other recycling benefits may be reduced sludge disposal costs incurred by other mitigation alternatives and less physical space for equipment.

a. Recycled Glycol Fluids. Recycling glycol may offer airport management lower disposal cost of effluent through the resale of recovered product to fluid manufacturers or to other secondary markets. Prior to using recycled glycols as the primary aircraft deicer/anti-icer fluid, recertification in accordance with established industry standards is necessary, for example SAE, ISO. In regard to pavements, recycled glycol fluids may be reused on the airfield pavements if they meet the appropriate glycol-based runway fluid specifications in AC 150/5200-30A, *Airport Winter Safety and Operations*.

b. Recycled Water. The limited availability and high costs of water for some airports may make recycling a cost-effective runoff mitigation alternative. Airport management can commit recovered water, if permitted, to irrigate airport landscapes, wash airport/aircraft equipment, or for other non-potable water uses.

30. ANAEROBIC BIOREMEDIATION SYSTEMS. Anaerobic bioremediation systems in conjunction with POTWs or detention basins can be an effective means to dispose of glycol-contaminated stormwater. The bioremediation system generally consists of a glycol contaminated stormwater collection and storage system, a bioreactor treatment system, and a gas/heat recovery system. Today many POTWs will only accept limited quantities of glycol-contaminated stormwater. Anaerobic systems, depending on the airport's discharge permit, can reduce BOD₅ concentration levels sufficiently to permit unrestricted disposal to a POTW. For example, one airport-tested system reduced the oxygen demand of incoming glycol-contaminated runoff by over 98%. For those cases where POTWs

continue to impose discharge restrictions, the lowered BOD₅ concentration level may be such to allow an increase to the permitted discharge rate. Regarding detention basins, the presence of high glycol concentrations usually makes complete treatment more difficult. Treatment under such conditions normally require considerably more energy for aeration systems and produce large amounts of excess biomass, which in turn, need proper disposal. Anaerobic systems not only reduce high BOD₅ concentration levels but produce

significantly less biomass. When biomass is a problem, anaerobic systems can use activated carbon as the media for attaching the biomass. Furthermore, these systems have demonstrated an additional ability to lower to non-detectable levels or remove “additive packages” that are necessary in deicer products from collected runoff. An economical benefit of the anaerobic process is that it converts glycol in runoff to methane gas that can be used for heating.

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APPENDIX 1. DESIGN OF INFRA-RED AIRCRAFT DEICING FACILITIES

A-1. Overview. The predominant method to deice airplanes relies on the application of aqueous solutions of freezing point depressant (FPD) fluids. In terms of *deicing* airplanes other methods have been employed, such as the mechanical removal of certain types of contamination from airplane surfaces or the placement of airplanes within a heated hangar to melt or loosen contamination. In terms of *anti-icing* airplanes, the only acceptable method continues to rely solely on the application of an appropriate anti-icing FPD. Today, all available FPDs are glycol-based products.

Recent technological developments in the ability of infra-red energy to deliver sufficient, targeted energy to contaminated airplane surfaces have achieved a level, as prescribed in paragraph A-11, that makes this method, *in conjunction with FAA approved airplane ground deicing/anti-icing program*, an alternative deicing method. This alternative method offers airport authorities an environmental benefit because it is supplemented with little or no FPD during the deicing process. However, since infra-red energy can support only the deicing process, airplanes requiring *anti-icing* protection will still require an application of an appropriate anti-icing FPD.

This appendix provides design standards and recommendations to build infra-red aircraft deicing facility (IDFs) using a new class of infrared devices intended for deicing operations as compared to those devices used in the heating industry. Paragraphs from the main body of this document or within this appendix will be cross-referenced. In the latter case, the referenced paragraph will contain the letter A, e.g. A-4, to designate its location in the appendix instead of the main document. Figure A-1 illustrates an IDF with an

entrance taxiway, an infra-red deicing structure, and an anti-icing pad just out of view.

A-2. Design Airplane. The design airplane used to design an IDF will be in many applications a composite of several airplanes. A composite allows the designer to take into account the most demanding airplanes physical characteristics in terms of sizes and shapes. For example, the composite takes into account maximum tail heights plus their shapes, such as the T-shaped tail section of Dash-8s, vertical heights of wings fitted with winglets, such as the Airbus 320, and variations in fuselage lengths within an airplane family, such as the Boeing 737 family.

A-3. Infra-red Deicing Facilities (IDF). IDF have the following basic components:

- a. Entrance taxiway,
- b. Infra-red deicing structure,
- c. Nighttime lighting,
- d. Computerized gas-powered infra-red energy unit (EU) system,
- e. Facility Operations Shelter,
- f. Anti-icing capability,
- g. Exit taxiway,
- h. Bypass taxing capability, and
- i. Runoff mitigation measure.

As optional equipment, IDF may have ice detection cameras as described in paragraph A-9.



Figure A-1. FAA Boeing 727-100 taxiing into an infra-red deicing structure.

A-4. Siting of Infra-red Deicing Facilities. IDFs shall be sited in accordance with Paragraph 5, *FAA Clearance and Separation Standards Affecting Deicing Facilities*. For air traffic control towers to initiate control and release of aircraft, the perimeter of the facility shall be marked in accordance with paragraph 19 (a) *Pavement Markings for off-gate Deicing Facilities*. With today's improved holdover times of available anti-icers, terminal or cargo ramp areas present promising locations for siting IDFs. For some airports however, acceptable sites along a taxiway may better complement the type of operation in use during winter season. Regardless of the chosen site, the adjoining ground surrounding an IDF needs to be properly graded and prepared to support aircraft rescue and fire fighting (ARFF) vehicles under dry conditions. The requirement for grading provides responding ARFF crews access to any section of the IDF.

A-5. Entrance Taxiway. IDFs shall have an entrance taxiway designed, marked, and lighted in accordance with AC 150/5300-13, *Airport Design*, AC 150/5340-1, *Standards for Airport Markings*, and AC 150/5345-46, *Specifications for Runway and Taxiway Light Fixtures*. The section of the entrance taxiway leading into the infra-red deicing structure shall be straight and long enough to permit the longest airplane to align its entire fuselage with the taxiway centerline prior to entering the structure.

A-6. Infra-red Deicing Structure. IDFs shall have an infra-red deicing structure where airplanes are deiced by an infra-red EU system.

a. Modular Truss Design. The structure shall be designed in accordance with the building code requirements for the jurisdiction having authority. The structure shall be of a modular truss design that offers the owner the flexibility to (1) accommodate changes in airplane physical characteristics and (2) relocate the above ground portion of the structure on a seasonal basis. The structural components shall be of an interchangeable type that offers a range of sizes from the same basic structural components in terms of expandable widths, lengths, and heights, each being independent of the other.

b. Modular Truss Construction and Framing Materials. Modular truss components used for framing shall be made of an aluminum alloy or steel. Steel structures shall be galvanized in accordance with ASTM A 123, *Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products*, to resist corrosion. Each supporting column shall be designed and anchored in accordance with the building code requirements for the jurisdictional having authority to resist imposed static and dynamic forces, such as, wind loads and snow loads. All components, cross members, fasteners, bolts, etc. shall be positively

secured to protect against loosening and the introduction of foreign object damage to airplane turbine engines and propellers.

c. Fabric Cover. IDFs shall be covered by a fabric material (walls and roof) that is flame-resistant in accordance with the large scale test in National Fire Protection Association (NFPA) 701, *Standard Method of Fire Tests for Flame-Resistant Textiles and Films*. Furthermore, the fabric cover should be easy to repair when damaged and of a PVC-coated fabric, as compared to laminated, to improve durability and to protect the base fabric from ultraviolet light degradation.

d. Lightning Protection. The structure shall be fitted with lightning protection in accordance with NFPA 78, *Lightning Protection Code*.

e. Structure and Installation Design Codes. The structure shall be designed in accordance with the building code requirements for the jurisdiction having authority.

f. Fire Safety Codes. The structure shall be designed in accordance with fire code requirements for the jurisdiction having authority.

g. Electric Code. Electric service for the structure shall be designed in accordance with the electric code requirements for the jurisdiction having authority. At a minimum, electrical service shall be installed in accordance with the provisions for aircraft hangars contained in Article 513, *Aircraft Hangars*, of NFPA 70, *National Electrical Code*. Furthermore, all wiring not enclosed in conduits/raceways shall be adequately supported, laced, or banded to reduce wear and damage as the result of jet velocities or prop wash.

A-7. Nighttime Lighting. The IDF shall provide nighttime lighting within the infra-red deicing structure and, if constructed, for the exterior anti-icing pad. Nighttime lighting helps ground personnel to perform de/anti-icing processes and airplane inspections more effectively. Interior lighting shall be restricted to electricity. Lighting for the exterior anti-icing pad shall be in accordance with Paragraph 10, *Nighttime Lighting*.

A-8. Sizing Infra-red Deicing Structures. The size of infra-red deicing structures shall be determined by clearance requirements that separate the structure framing/infra-red EUs from the design airplane.

a. Length of Structure. The length of the structure shall equal the length of the design airplane fuselage plus a length for an overhead protective cover (PC). The PC, which is equally divided front and back of the total fuselage length, serves to reduce or

eliminate the amount of falling precipitation onto airplane surfaces. The PC length shall be in accordance with table A-1. Sites customarily experiencing large horizontal dispersion of falling snow and/or frozen precipitation, such as, a result from strong winds, can minimize such dispersions by orienting the facility centerline perpendicular to such winds.

Airplane Design Group (ADG)	Protective Cover Length Feet (meters)
ADG II and Smaller	20 feet (6.1 m)
ADG III and Larger	30 feet (9.1 m)

Table A-1. Protective Cover Lengths

b. Height of Structure. The height of the structure shall be such that the closest point of the infra-red EUs and structural framing clears the most demanding airplane tail section by 10 feet (3.05 m). Precaution in selecting this dimension is necessary since the vertical heights of airplanes vary according to tire pressures and taxiing weights, e.g., operating design empty weight versus maximum design taxiing weight. Therefore, the designer shall take into account the maximum height of all tail sections and their shape as provided by the airplane manufacturer(s).

c. Roof Size. The roof of the structure shall be arched to maximize the delivered radiant energy by the infra-red EU system and thereby reduce deicing times. Furthermore, the arched-roof shall be designed with open ends and free of ceiling pockets to eliminate the accumulation of engine exhaust and other vapors. In accordance with NFPA 409, a 10-foot (3.05 m) clearance shall be provided between the arched framing/infra-red EUs and the most demanding airplane wing configuration, e.g., height of wingtips, winglets. The designer needs to take into account height variations of wingtips, especially airplanes with winglets, when airplanes are not fully loaded with fuel. To illustrate, Boeing publication D6-58326-1, *747-400 Airplane Characteristics for Airport Planning*, shows winglet on the Boeing 747-400 range approximately from 22 feet (6.7 m) to almost 31 feet (9.3 m) above the ground. The designer shall use the highest ground clearances provided by airplane manufacturers.

d. Width of Structure. The width of the structure shall provide the clearance measured horizontally between wingtips/winglets and the structural framing/infra-red EUs in accordance with table A-2.

e. Wall Egress. Each wall shall have one egress between two adjacent columns to provide an additional evacuation route for passengers during an emergency. The opening shall be in accordance with the jurisdiction having authority, but not less than 4 ft (1.2 m) by 8 ft (2.5m). The egress should be located behind the wing section. If the jurisdiction having authority permits a single door for the opening, then it shall be of a non-locking type that opens outward.

Airplane Design Group (ADG)	Clearance Distance Feet (meters)
ADG II and Smaller	10 feet (3.0 m)
ADG III	15 feet (4.6 m)
ADG IV and Larger	20 feet (6.1 m)

Table A-2. Horizontal Clearances

f. Floor Design. The floor shall be designed to carry the maximum anticipated taxiing weight of the design airplane in accordance with paragraph 21 (a), *Pavement Designs*. The floor shall be sloped to allow for drainage (see paragraph A-11(g)). If an infra-red deicing structure is placed over an existing taxiway, the taxiway width shall be expanded up to the supporting structural columns of the structure. In this case, the transverse grade of the taxiway shall be continued for the full-expanded width. The portions of floor that are wider than the existing taxiway shall have a load-bearing capacity not for airplanes but for the expected vehicle traffic within the structure. The edges of the floor in all cases shall be free of any type of continuous curbing.

g. Drainage Design. The floor shall be designed to prohibit melt off and other runoff from ponding within the structure and direct runoff for proper treatment. Any interior drains should be located near the perimeter of the floor to minimize their exposure to

aircraft and vehicular traffic. When used, high strength drainage boxes and covers shall be designed in accordance with AC 150/5320-5. Additionally, the design of the drainage system shall take into account the ability of the ARFF service to respond unimpeded to emergencies and for passengers to evacuate the structure safely. For example, the drainage system leading away from the structure shall not be of an open ditch design.

h. Floor Markings. The floor shall have two types of markings. First, the floor shall be marked with a taxiway centerline in accordance with AC 150/5340-1. Second, the floor shall be marked with a nose wheel stop mark to indicate the proper placement of airplanes under the infra-red EU system. The facility operator should determine the shape and color of the stop mark. Since the infra-red EU system offers the operator the flexibility for zonal application of energies, that is, energizing portions of the system, more than one stop mark may be needed to process smaller airplanes.

A-9. Optional Equipment - Ice Detection Cameras. Infra-red deicing structures may have as optional equipment ice detection cameras to allow facility operators the ability to scan airplane surfaces prior to and after airplanes are exposed to infra-red energy for the presence of frozen contamination. The cameras shall meet the requirements of SAE Aerospace Standard (AS) 5116, *Performance Standard for Airplane Ground Ice Detection System, Airplane/Ground Based*. Cameras may be either a hand-held system or fixed system with color monitors that show degrees of frozen contamination. The color monitor for hand-held cameras are built into the camera itself while for a fixed system the color monitor is a separated piece of equipment. If a fixed system is used, the cameras should be placed in a manner that maximizes the surface viewing areas of airplanes.

A-10. Facility Operations Shelter. The infra-red deicing structure shall have an enclosed, temperature controlled shelter for facility personnel with a separated operations room to house the computer system that controls the infra-red EU system, a printer, color monitor(s) for the fixed infra-red ice detection camera(s), telephones, and other equipment necessary to the operation. The intent of the separated operations room is to eliminate inadvertent distraction on system operator(s). The operations room shall have a window(s) that allow personnel running the infra-red EU system a full view of the operation. Location of the shelter shall be in accordance with the clearances of table A2. A suitable portable fire extinguisher(s) in accordance with NFPA 10, *Standard for Portable Extinguishers*, shall be provided.

A-11. Computer-Controlled Gas-Powered Infra-red EU Systems. Gas-powered infra-red EU systems

need to deliver sufficient radiant energy at appropriate wavelengths that target specific types of contamination without damaging airplanes. Furthermore, systems shall be computer-controlled to ensure greater operational control and improved efficiency to remove contaminants. Computer control allows specific infra-red EUs to vary their energy levels and exposure times independently for zonal applications. Thus, operators can tailor the deicing process to tackle the differences in airplane types and sizes and the variations in the types and thickness of contamination adhering to the airplane. Therefore, systems shall deliver infra-red energy in accordance with the two-part test criteria from the following subparagraphs. An independent lab shall evaluate the system that will be installed at the airport thereby evaluating the actual energy levels that airplanes will be subjected to. The testing parameters allow the flexibility for conducting system evaluations either outdoors (preferable due to the separation requirements of the test and limit the size of infra-red EU systems) or in a very large cold chamber. FAA reserves the right to retest all candidate infra-red EU systems at its discretion.

a. Purpose of Contamination Removal and Heated Panel Tests. Acceptable infra-red EU systems are those that pass two interrelated tests. Test procedure (TP) #1, Contamination Removal, evaluates the system's capacity to deliver sufficient focused infra-red energy to remove artificially produced ice layers of specified thicknesses from test panels within specified time frames. Test procedure (TP) #2, Heated Panel, evaluates the system's performance settings used in TP#1 to evaluate the potential for the system to overheat uncontaminated (cleaned) test panels beyond a prescribed maximum surface temperature. System evaluations shall be conducted in accordance with the test methods outlined in subparagraph A-11 (d). Although the evaluation tests are based on a 10-foot (3.05 m) separation between the panels and infra-red EU system, in actuality the majority of the infra-red EUs within a system in field applications will operate at much greater distances. It is the intent for infra-red EU systems to work effectively at greater distances such as 20 feet, 30 feet, or more (6.0 to 9.1 m) from some aircraft sections. For example, some infra-red EUs aimed at the mid wing sections and the upper fuselage will be placed more than 10 feet away.

b. Test Locations and Conditions. Independent labs shall conduct evaluations either in a large cold chamber or, preferably, outdoors under the following conditions: cold chamber or ambient outdoor temperature shall be at or below 28°F ± 2°F (-2.5°C ± 1.0°C) with winds not exceeding 10 mph (16 km/hr.)

c. Independent Testing Lab Report. The independent testing lab report shall contain:

(1) for TP#1 the actual observed times necessary to remove completely the contamination thicknesses for each tested panel,

(2) for TP#2 a temperature rise over time profile graph that notes the highest recorded temperature for each tested panel,

(3) photographs showing the system's setup over the inclined supporting structure that holds the test panels,

(4) the separation distances from the infra-red EUs to the test panels,

(5) ambient outdoor or cold chamber temperature and wind conditions at the start and conclusion of the evaluations, and

(6) a statement of success or failure for the candidate system. Specific failure(s) of a testing requirement(s) shall be noted.

For pass/fail determinations, complete ice removal is defined as the absence of ice, which has undergone a physical change to water or vapor, from the entire upper surface of a test panel excluding water droplets from the drip edge. Also, since the testing panels are inclined, portions of ice sheets that disbond and slide off the testing panels due to the effect of gravity are considered to be "completely removed", i.e., meets the intent of TP #1.

d. Testing Methods and Materials for Contamination Removal and Heated Panel Tests.

Testing Materials:

(1) **Test panels**, six in all, shall be three-foot square by 1/8th inch thick flat sheets of aluminum alloy AMS 4037 in accordance with SAE AMS 1428, *Fluid, Aircraft Deicing/Anti-icing, Non-Newtonian (Pseudoplastic)*, SAE Types II, II and IV, latest edition.

(2) **Artificial ice** shall be produced by freezing American Society for Testing and Materials (ASTM) D 1193, *Reagent Water*, Type IV water.

(3) **Inclined supporting stand (ISS)** to secure and support three separated test panels simultaneously in an inclined position. The ISS shall be able to secure test panels so that the lower drip edge of the test panels are 3 feet \pm 1 inch (91.5 cm \pm 2.5 cm) above the floor and provide a +10 degree \pm 1.0 degree incline from the horizontal. The ISS shall have a means to eliminate sagging of test panel, which in turn may cause breakage of the artificial ice layer. For example, ISSs should have a center structural member to eliminate sagging. Furthermore, ISSs should be on wheels/casters to allow

it, once test panels are secured, to be rolled into position beneath the candidate infra-red EU system.

Test Procedure: TP #1 Contamination Removal

Step 1: Setup of Overhead Infra-red EU System. Position the candidate infra-red EU system directly overhead of the ISS with three clean test panels (see A-11(d)(3) for height requirements) such that the lowest part of the system (EU housing) is at a distance of 10 feet \pm 1 inch (305 cm \pm 2.5 cm) above the top of the three test panels. Regardless of the system's arrangement all EUs shall be at least 10 feet (305 cm) away from the test panels. Mark the location of the ISS on the floor. Floor markings will later be used to reposition the ISS with secured test panels for actual test runs.

Step 2: Artificial Ice. Six test panels, individually numbered, shall be prepared with an artificially produced ice layer. Test panels shall have temporary walls attached to their edges to create a 1/2 inch (1.27 cm) high dam effect. For example, the dam effect can be obtained by using a paraffin wax, silicon, or a caulking compound to hold water. Pour Type IV water into the six test panels to obtain three test panels with a depth of 1/8 inch \pm 1/16 inch (0.32 cm \pm 0.16 cm) and three test panels with a depth of 1/4 inch \pm 1/16 inch (0.64 cm \pm 0.16 cm). To help measure the water depth, five small rubber washers having the prescribed depths can be used. The five rubber washers shall be placed in a "t pattern" (not an "x pattern") one centered and four placed approximately 6 inches (15.25 cm) from the edges. Test panels with washers shall be cold stored at 25-28 °F (-4.0 to -2.5 °C) for at least 8 hrs to allow the Type IV water to freeze completely. All temporary walls are to be removed carefully prior to exposing test panels with infra-red energy.

Step 3: Inclined Test Panels. Carefully place three test panels with 1/4-inch ice thickness separated horizontally by 1 foot (30.5 cm) onto the ISS. Make sure that the lower edge of test panels are slightly below the ISS, approximately 1/2 inch (1.25 cm), to allow ice melt to flow freely off the inclined test panels. *Precaution:* Panels need to be secured in a "flat as possible" manner to eliminate ice breakage due to sagging or bending of the test panels.

Step 4: Time Recording. After the infra-red EU system achieves equilibrium (expected settings in actual field operations) roll the ISS with secured test panels underneath the system and reposition the ISS using the step #1 floor markings. Commence time recording immediately. The clock is stopped for each test panel once all observable ice contamination is removed from the entire upper surface. Record the time required for

all three test panels. Test panels can have water droplets on the drip edges and panels need not be completely dried. The longest time duration recorded for this ice thickness shall be used to determine acceptance in accordance with table A-3. Repeat steps #3 and #4 with the 1/8-inch contaminated test panels.

Contamination Type and Thickness	Maximum Removal Time Permitted (minutes)
1/8-inch Ice	8
1/4-inch Ice	15

Table A-3. Acceptance Criteria for Contamination Removal by Infra-red EU Systems

**Test Procedure: TP #2
Heated Panel**

Step 1: Setup of Overhead Infra-red EU System. Evaluate the identical infra-red EU system and ISS setup used for TP #1 step 1.

Step 2: Acclimated Test Panels. Cold store six clean, uncontaminated test panels at 25-28 °F (-4.0 to -2.5 °C) for 3 hours.

Step 3: Inclined Test Panels. Secure three clean, uncontaminated test panels in the same position as described in TP #1 step 3.

Step 4: Thermocouple Placement. Attach two thermocouples down the middle of each test panel in a manner to record the surface temperature of the test panel. The first thermocouple shall be placed 1-foot (30.5 cm) from the top of the test panel. The second thermocouple shall be placed 1-foot (30.5 cm) below the first thermocouple. Cover the housing of the thermocouple in such a manner to minimize a temperature rise in the thermocouple itself as a result to infra-red energy exposure. Thermocouples used shall have an operating temperature reading range from +10 to +250 °F (-12 to +121 °C) with a tolerance of 1 ° F (0.5 °C).

Step 5: Time Recording. Energies the infra-red EU system to the same power settings used to remove the 1/4-inch ice contamination in TP#1 step 4. Once the system is in equilibrium, reposition the ISS and commence time and temperature recording. Thermocouples shall record the continuous surface

temperature rise of each test panel for a total exposure time of 10 minutes. Repeat TP#2 steps 3, 4 and 5 for the 1/8-inch power settings. Acceptable systems are those where the maximum temperature rise as measured in step 5 of TP #2 for all six test panels remain below 150 °F (65.5 °C).

A-12. Installation of Infra-red EU Systems. Installed infra-red EU systems shall be gas-fueled. Individual infra-red EUs that comprise the system shall be at least 10 feet (3.05 m) away from airplane surfaces for the airplanes expected to use the facility. Gas-fueled infra-red EU systems, which includes the gas supply and, if present, storage vessels, shall be installed in accordance with NFPA 54, *National Fuel Gas Code*. The main gas supply system(s) shall be equipped with manually operated control valves and emergency safety shutoff valve(s). The manually operated valves shall be located at strategic points inside or immediately outside the structure so that the main gas supply can be shut down quickly in the event of an emergency. A placard shall indicate the location of all red-coded control and emergency safety shutoff valve(s).

A-13. Infra-red Energy Unit System Configuration.

a. Infra-red Energy Zones. The entire infra-red EU system shall be placed in an overhead configuration that provides effective infra-red energy to the design airplane. Additionally, the configuration shall consist of independently operated energy zones that allow the operator to use all energy zones in the system or pre-selected energy zones. For example, the operator could use only those energy zones that are better suited for small airplane applications.

b. Maintenance. Infra-red EU systems shall be located in areas that do not subject them to injury by aircraft or ground equipment. Provisions shall be made to assure accessibility to individual infra-red EUs for scheduled maintenance purposes.

A14. Computer Hardware/Performance.

a. Hardware. Infra-red EU systems shall employ computer hardware consisting of a processing unit, color monitor, and printer. The computer shall have the operating capability to perform software routines with sufficient speed and memory for data evaluation/records.

b. Software Routines. Software routines may be initiated by keyboard and/or by a touch screen monitor. The software shall have routines that allow the operator to:

- (1) pre-warm the structure,

(2) regulate the amount of focused infra-red energy through variable power settings to remove the various types of contamination and various airplane configurations,

(3) regulate the duration of infra-red energy application for each power setting,

(4) energize specific infra-red EUs and at different infra-red energies for zonal applications,

(5) shutdown the entire system by a single command button,

(6) print records detailing airplane designation, time of entry to structure, energy settings used and their duration, and time of completion,

(7) warning(s) as required by the authority having jurisdiction that indicates a problem has occurred with the infra-red EU system, and

(8) automatic system that self-imposes a shutdown when the system acknowledges a problem.

A-15. Anti-icing Capability. IDFs shall provide the facility operator the capability to anti-ice airplanes in one of two ways.

a. Interior Anti-icing Operations. The clearance criteria for sizing infra-red deicing structures is such that sufficient clearance is afforded for deicing trucks to perform anti-icing operations within the structure. Depending on where the infra-red deicing structure is placed, a paved vehicle staging area may be necessary. That is, deicing trucks shall have a staging area(s) that allow untreated and treated airplanes to enter and exit the structure safely.

b. Exterior Anti-icing Pad. If a determination is made to perform exterior anti-icing operations, then a dedicated uncovered anti-icing pad shall exist. Generally, the anti-icing pad will be located directly in line with the infra-red deicing structure. It is recommended that the anti-icing pad, which consists of the aircraft parking area and the vehicle maneuvering area, be at least 20 feet (6.0 m) from the opening of the infra-red structure. The anti-icing pad shall be marked with a taxiway centerline and lighted in accordance with AC 150/5340-1 and AC 150/5345-46. The length of the anti-icing pad shall be in accordance with Paragraph 16, *Aircraft Deicing Pads*. The anti-icing pad shall be 10 feet (3.0 m) wider than specified in paragraph 16. The 10-foot (3 m) increase shall be used to provide a 10-foot (3 m) vehicle safety zone for parking and staging mobile deicing trucks.

A-16. Exit Taxiway. IDFs shall have an exit taxiway designed, marked, and lighted in accordance with AC 150/5300-13, AC 150/5340-1, and AC 150/5345-46. The section of the exit taxiway leading out of the infra-red deicing structure must be straight and long enough to permit the longest exiting airplane to completely clear the structure before initialing a turn.

A-17. By-pass Taxiing Capability. IDFs shall provide a taxiway route to by-pass the IDF in accordance with Paragraph 11, *Bypass Taxiing Capability*.

A-18. Runoff Mitigation. IDFs shall have a runoff mitigation structure(s) that permits proper disposal of glycol-based products in accordance with Chapter 5, *Water Quality Mitigation*.

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